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RUSTLESS PIPE FOR WAR AND PEACE

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Introduction

OIL, gas, soil, air, and salt water attack and shorten the life of oil-field steel. Of these enemies, salt water is the most destructive. The use of nonmetallic pipe helps to answer the wartime demand for "more oil with less steel," and since there is no V-Day in the endless fight of rust against steel, whatever helps in war will be helpful when war is over. With this in mind, the Illinois State Geological Survey set up the project of investigating corrosion-proof pipe and couplings, the results of which are described here. An earlier project, along related lines, resulted in the successful running and cementing of fiber-pipe casing in a 500-ft. well, an operation described in The Oil and Gas Journal for May 28, 1942.

Scope of the Investigation

The most satisfactory corrosion-proof pipe-forming materials were found to be of the following compositions: (1) coal-tar pitch with a binder of macerated paper and wood fiber; (2) cement with a binder of asbestos fiber, and (3) both plain and reinforced plastics.

We made pipe which we called "Glascrete," consisting of highly

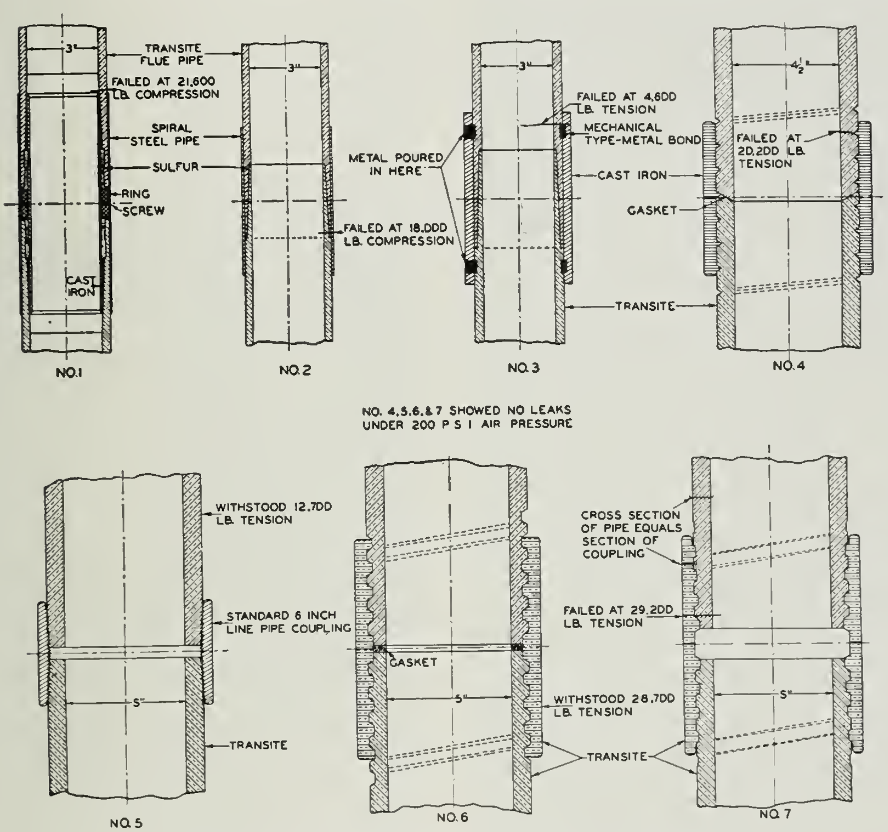


Fig. 1—Seven methods of coupling asbestos cement pipe

Fig. 2—(Left) A section of asbestos cement pipe at 1, joint 4 at 2, joint 6 at 3, joint 3 at 4, and joint 5 at 5

Fig. 3—(Right) The joints after being tested to failu Points of failure are indicated for each joint in Fig.

compressed cement with glass-fiber reinforcement which we tested and found incapable of withstanding shock and suddenly applied loads. However this experiment suggested the substitution of plastics, reinforced with glass, for cement. We found that threaded couplings made of cast iron, steel, stainless steel and plastic, either plain or reinforced with glass fiber or metal, could be used on threaded asbestos-cement pipe. This pipe seemed to require couplings of a material more elastic than the pipe itself. Stainless steel and plastic pipe were found to be too expensive for a complete assembly, but couplings of these materials, used to join lengths of fiber or asbestos-cement pipe, were sufficiently economical in view of the small fraction of the entire pipe line occupied by the couplings.

Sections of fiber, asbestos-cement, and plastic pipe were tested for ability to resist bursting and collapse. Pipe and coupling assemblies were tested for strength to resist parting both in the pipe and at the joint, and leakage at the joint. Nonmetallic pipe lines have heretofore been connected by means of a variety of shoved joints, made tight either by friction holds or rubber gaskets. The couplings which, because of the greater strains on them, should be the stronger part of nonmetallic pipe lines, have always been the weaker, because advantage has never been taken of the great inherent strength of a threaded connection. A good deal of time was devoted to the problem of thread ing pipe and couplings with results which seemed to be promising. It was found that threading by grinding with high-speed abrasive wheels overcame many of the difficulties previously thought to be insurmountable. Couplings were made of asbestos cement, cast iron, steel, stainless steel, plain plastic, and glass-fiber and metal - reinforced plastic. Tests were made on the pipe alone and on the pipe and coupling assembled.

Fiber Pipe Tests

The composition of fiber pipe is 75 per cent coal-tar pitch and 25 per cent macerated paper and wood fiber. It is made on mandrels in 5 and 8 ft. lengths. Designed originally for use as electric conduit, it has been successful for this purpose under a wide variety of conditions for many years. The weight of fiber pipe is only 16 per cent of the weight of steel pipe of equal cross-section.

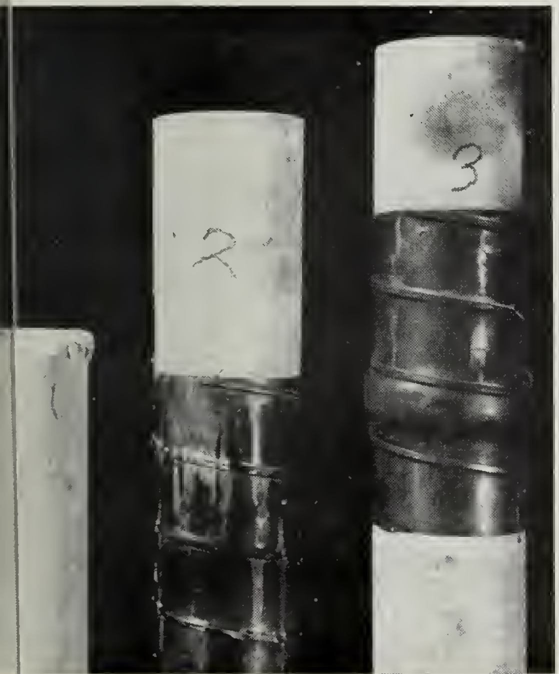
Fiber conduit is made to meet three classifications. The second of these three commercial grades was tested for strength at Halliburton Oil Well Cementing Co.'s Flora plant. The pipe was destroyed by bursting at an average pressure of 220 psi. Collapse occurred at 420 psi. Ultimate tensile strength was 2,500 psi., and ultimate compressive strength 5,000 psi. These degrees of strength prove it is usable for gravity lines and for cemented-in casing for shallow wells.

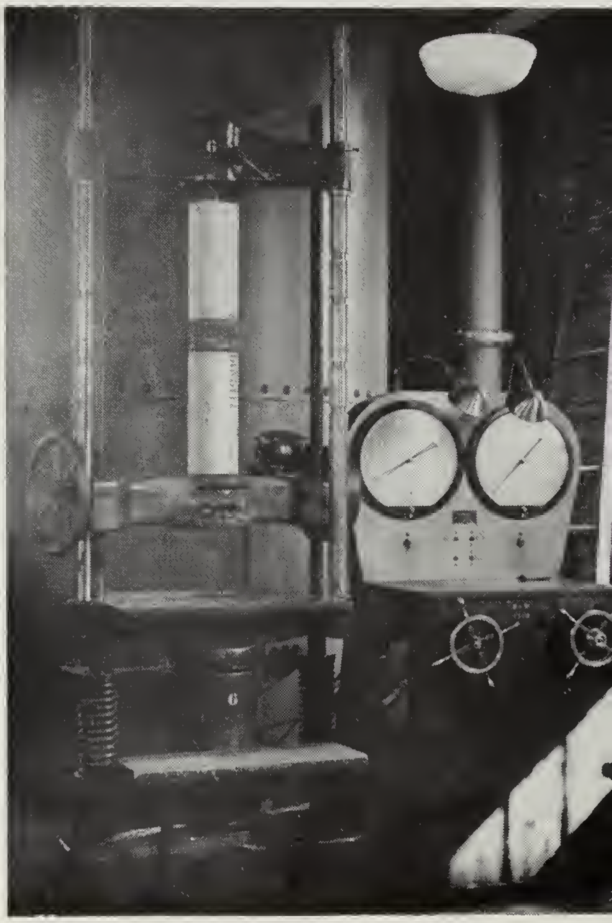
No leakage tests were made because of the nature of the joint. Pipe supplied us was not threaded but the joint was made by tapering the end of the pipe and driving it into an oppositely tapered coupling. The elasticity of the coupling binds the pipe and provides a friction grip. The ability of such a joint to resist separation varies over a considerable range and is therefore not reliable except for surface gravity lines. Threaded fiber-pipe joints connected by threaded stainless steel or plastic couplings provide a practical corrosionproof string for surface lines and for cemented-in casing for shallow wells. The plastic couplings are stronger than the pipe, and the joint is leakproof.

Tests with dilute acids and alkalis did not affect the fiber pipe, and immersion in crude oil for 8 months produced only a slight tackiness of the exposed surfaces. These corrosion-resisting qualities make it especially useful for salt-water disposal, both for surface lines and for short strings of subsurface casing.

The main difficulty with the pipe of this composition is that severe shocks such as are often experienced in shipment and other handling may produce crazing, which is difficult to detect but which weakens the

'. 4—Joints 1 and 2 (shown also in scale sections on Fig. and a section of similar asbestos cement pipe for com-rison. No tension test was made, but compression tests stroyed joint 1 (center) at 21,000 lb. and joint 2 (right) 18,000 lb. The pipe (left) failed in compression at 200 lb., showing that the joints weakened the pipe . 5—(Right) Testing machine in the Talbot laboratory on ich all the tests were made. The joint being tested is shown in Fig. 1 as No. 5, the 6-in. pipe coupling





pipe. It is also subject to the defect of cold bending under its own weight. To correct both these imperfections as well as to increase its strength for every kind of load, the pipe may be cement lined by the same process that is used to protect metal pipe against corrosion. Cement-lined fiber pipe may be further strengthened by first incorporating coiled-wire reinforcement sprung against the inside of the pipe and then cementing it in, the resulting reinforced cement inner sheath providing a great increase in the pipe's resistance to bursting. This makes the pipe suitable for pressure lines on the surface and cemented-in casing for deeper wells.

Asbestos-Cement Pipe

Asbestos-cement pipe is made on mandrels which pick up a coating of cement, water, and asbestos fiber. A roller above the mandrel subjects the coating to high pressure while it is being built up. It is made in several grades, from flue pipe at the bottom of the scale up to pipe that stands 200-lb. pressure.

Commercial lengths are 13 ft. Couplings are made in a variety of ways but none are threaded so that when used in any but a horizontal position the line must be supported to keep it from pulling apart. The usual uses are for electric conduits, vent pipes, and water mains. It has been used as a well casing with screwed joints in only one installation. Brundred Oil Co. has used this pipe with perforated beveled telescoping joints for liners for the bottom hundred feet of oil wells in Pennsylvania.

Tests of Joints for Asbestos-Cement Pipe

Seven kinds of experimental joints for asbestos-cement pipe were devised and tested and are illustrated by scale drawings in Fig. 1 and by photographs in Figs. 2, 3, and 4.

Joint No. 1 was made by beveling two pieces of low-strength 3-in. i.d. flue pipe and joining them by a coupling consisting of two eccentric metal cylinders held together at the center by a metal ring. The inner metal cylinder was cast iron and the outer was light-weight spiral pipe. The inner metal ring and the pipe were grooved for a mecanical bond that would be formed when the space between the inner metal ring and the pipe is filled with any setting material poured in and allowed to harden. The bond in this case was made with sulfur.

The joint was tested to failure by compression at 21,600 lb. It was not tried in tension.

Joint No. 2 consisted of male and female tapered 3-in.-i.d. asbestos cement-flue pipe and a single outside cylinder of light-weight steel spiral pipe, all bonded with sulfur poured into the space between the ring and the inner pipe section, after which

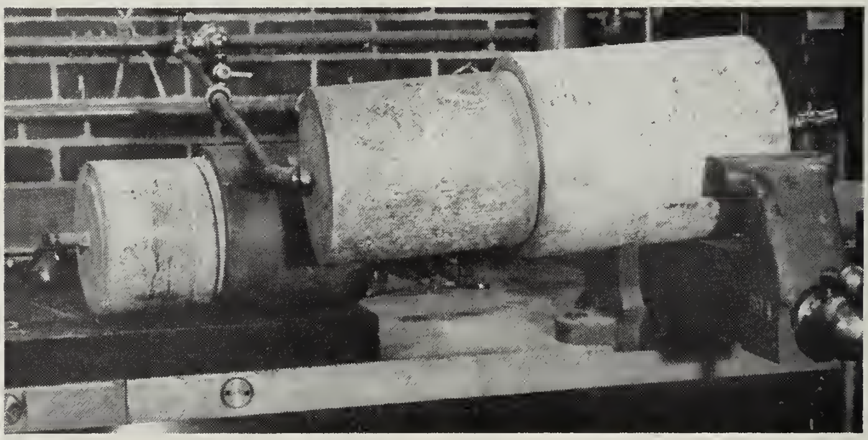


Fig. 6—Equipment for leak test, showing joint 6 (Fig. 1) being tested with air at 200 psi. Joint 4 is in background ready to be tested

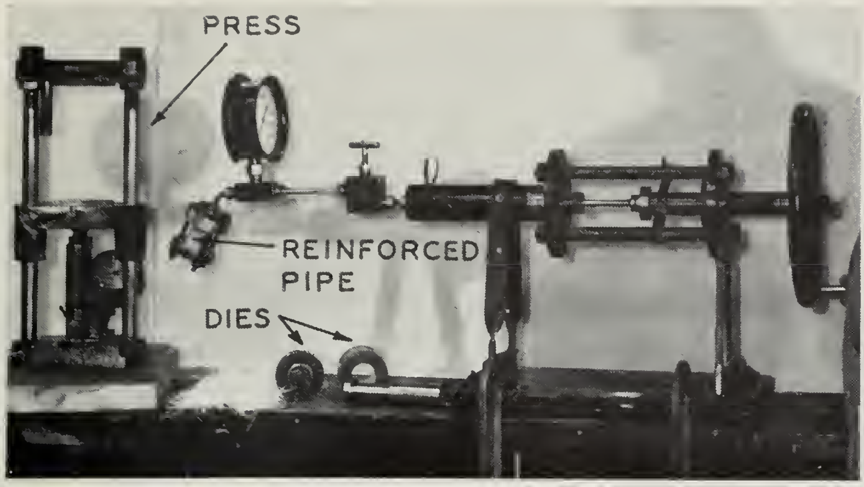


Fig. 7—The press and dies used in making and the hydraulic pump used in testing glass-fiber-reinforced cement pipe, and plain and reinforced plastic couplings. The test pieces of glasscrete (glass-fiber-reinforced cement) pipe and plastic couplings are made under high pressure in the press and are tested with the hydraulic pump for strength to resist bursting

the outer section was run into place. This joint was destroyed in compression at 18,000 lb. Joints 1 and 2 are shown in Fig. 4.

A section of 3-in. i.d. asbestos-cement flue pipe (also shown in Fig. 4) was destroyed in compression in order to compare its behavior with that of the jointed pipe. It failed at 25,200 lb. showing that the joint was weaker than the pipe.

Joint No. 3 was made to provide a joint with a positive mechanical bond between the two pieces of tapered male and female 3-in.-i.d. asbestos-cement flue pipe and a cast-iron outer cylinder. Grooves were cut to register in both pipe and coupling and the hollow ring so formed was poured full of type metal. The joint proved stronger than the pipe. (Joints 1, 2 and 3 were made with low-strength pipe and are not comparable with the following tests made on 200-lb. pipe. They would be too weak and too slow in assembly to be practical in the oil field).

Joint No. 4 consisted of a cast-iron screwed coupling connecting two sections of 5-in.-i.d. 200-lb. threaded asbestos-cement pipe. The threads are one to the inch, the cross-section of the metal thread being one-fourth of the cross-section of the asbestos-cement thread. (Fig. 10). The threads were made by grinding (Fig. 11). The smaller section of the metal presents greater strength to resist stripping than the greater section of pipe, as was shown in the test wherein the joint failed in the pipe thread. This idea should be incorporated in the design of any metal coupling for nonmetallic joints of pipe.

Joint No. 5 is a standard steel 6-in. i.d. line collar, eight threads to the inch, connecting two sections of 5-in.-i.d. 200-lb. asbestos-cement pipe threaded on a standard pipe-threading machine. It is the simplest joint to make because all the work is standard steel pipe practice. (The thread on the pipe should be ground with an abrasive wheel, not cut on a pipe machine.) The test of this pipe compared with the coarser, deeper-cut threads on joint No. 4 just described and joints Nos. 6 and 7 give evidence that the best number of threads per inch for asbestos-cement joints should be somewhere between eight and one thread per inch. Four is suggested. A stainless-steel coupling should replace the ordinary steel. It would be non-corrosive, could be made very light in weight, and is the material recommended for all metal couplings on nonmetallic pipe. Methods of manufacture developed during this war have greatly reduced the cost of stainless steel. Its expense would be divided over the whole pipe line assembly and would therefore be reasonable as it would occupy only one-thirtieth of the length of the line.

Joint No. 6 was the first trial of a full asbestos-cement joint. A coupling of 6-in.-i.d. 200-lb. pipe was threaded, one thread to the inch, and connected to two sections of 5-in.-i.d. 200-lb. pipe similarly threaded. The thread on the pipe was tapered.

Joint No. 7 was of the same size as joint No. 6. The taper was such that the cross-section of the pipe and of the center of the coupling were equal. The asbestos-cement couplings for joint Nos. 6 and 7 lacked the elastic gripping power which is present in steel and plastic couplings.

Tests on Asbestos-Cement Pipe

Compression.—A section of 3-in.-i.d. flue pipe was destroyed by compression in the apparatus shown in Fig. 5 at the Talbot laboratory, University of Illinois, under the direction of Professors Frank Richart and V. P. Jensen. It failed at 14,000 lb. It was not destroyed in tension but it was evident that it would give a poor account of itself. The material is low grade.

Bursting.—A section of 5-in.-i.d. 200-lb. pipe shown in Fig. 2 (top) was tested at the factory to 800 psi. without failure. The ultimate strength is 1,100 psi.

Collapse. — The section of pipe shown in Fig. 2 (bottom) was subjected to 2,000 psi. compression without failure at the Bradford Supply Shop at Robinson, Ill. The section shown in Fig. 2 (top) was tested to 1,750 psi. without failure. This specimen consisted of two sections of 4½-in.-i.d. 200-lb. asbestos-cement pipe connected by a pitch fiber coupling. The pipe was prepared by machining the ends of the pipe, placing a rubber gasket at each end, and fitting them with metal caps connected through the pipe with a rod which was tightened with nuts on each end of the rod where it extended through the cap.

The pipe to be tested was placed inside a 7-ft. joint of extra heavy 10-in. casing ending in couplings into which were screwed swedged nipples, one of which was connected to the hydraulic pump and the other to an outlet valve. Air was released at a valve on the top side of the casing.

Valves on the pump would not hold beyond the 2,000 and 1,750-lb. pressures. When removed from the casing the asbestos-cement pipe was undamaged.

These tests prove that the pipe is

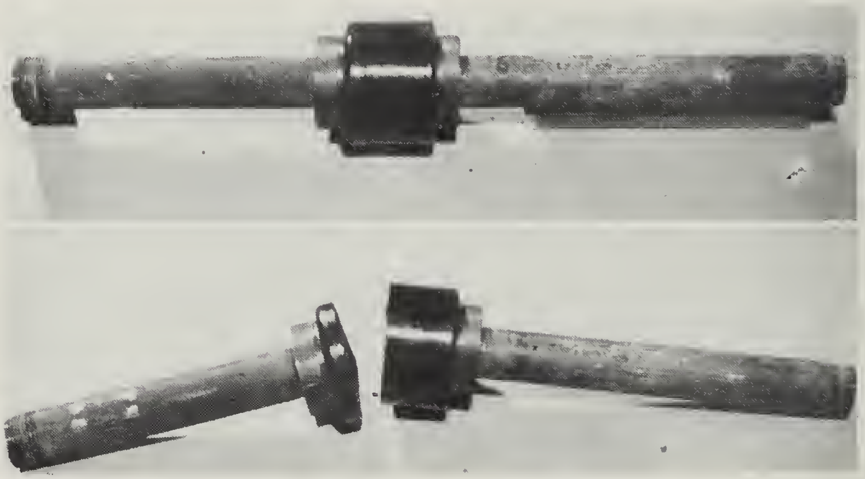


Fig. 8—A 2-in. plastic coupling connected to pipe ready for a tensile test and the same coupling after testing to destruction. The threads did not strip. The coupling parted through the last thread at the center. Reinforcement would give increased tensile strength

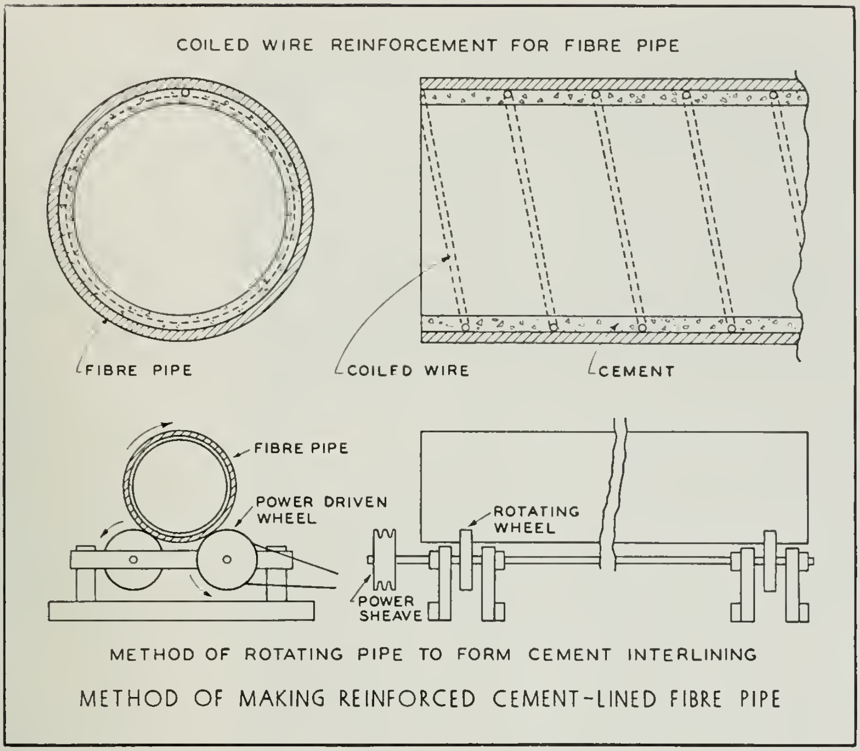


Fig. 9—Illustration of method of lining fiber conduit with cement. Cement lining increases power to resist collapse and metal reinforcement prevents bursting

competent to withstand ordinary salt-water-disposal loads.

Tests for Tensile Strength

Tests for tensile strength were made on the apparatus shown in Fig. 5, at Talbot laboratory, under the direction of Professors Richart and Jensen. They were made primarily to investigate the possibility of using the pipe for cemented-in casing for salt-water-disposal wells.

Joint No. 3 (see Figs. 2 and 3) failed in the thinnest part of the pipe next to the type-metal mechanical bond at 4,600 lb. The material was low-grade flue pipe and the result is not comparable with the other results described.

Joint No. 4 (see Figs. 2 and 3) failed in the thread at the outer edge of the coupling at 20,200 lb.

Joint No. 5 (shown on Figs. 1 and 5) went to 12,700 lb., at which point the plug in the end of the pipe pulled out and the test had to be stopped. On a later test, after the plug had been reset, the thread on the transite pipe stripped at 22,000 lb. This was an important finding as it proved that shallow threads cut on asbestos-cement pipe had great strength.

Joint No. 6 (Figs. 2 and 3) withstood a pull of 28,700 lb., at which point the pipe pulled apart at the point where the pins holding the rod weakened the pipe.

Joint No. 7 (Fig. 1 only) failed in the last thread at center of the coupling at 29,200 lb.

Joints No. 1 and 2 were not tested for tensile strength.

These tests show that tensile strength is sufficient for loads usual in salt-water disposal through surface lines and for cemented-in casing for shallow wells.

Tests for Tightness of the Joints Against Leakage

All the joints from No. 3 to No. 7 inclusive, were tested for leakage with a setup as shown in Fig. 6. Three pressures were used: (1) water

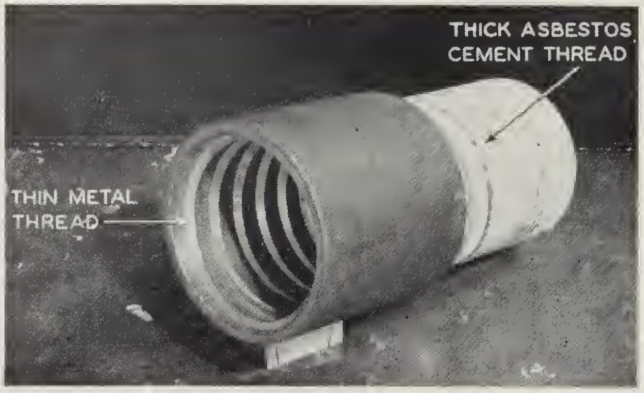


Fig. 10 — A metal coupling the projecting thread of which has a thin section, and asbestos cement pipe the thread of which has a thick section. This is an attempt to proportion the cross-section of each material to its relative strength to resist stripping

at city pressure of 55 psi.; (2) water at pump pressure of 100 psi.; and (3) air at 200 psi. Rubber gaskets were used in most cases but gaskets made of fabric and graphite were equally effective. All the joints were leakproof at the pressures applied, but when used as casing higher pressures will be encountered.

Glascrete

In an effort to find a material which would have the corrosion-resistant qualities of cement pipe and not require the use of asbestos, a scarce material, experiments were tried with cement reinforced with glass fiber. The pipe could not withstand shock although it proved to be a fairly satisfactory material to withstand slowly applied loads. Fig. 7 shows the press and dies with which the pipe was made and the reinforced pipe in the hydraulic testing machine. Glass fibers are pictured between the press and the dies. The same apparatus was used in making and testing plastic couplings.

Results from tests show too much variety to lead to dependable conclusions, but even if the results under slowly applied loads could be duplicated in manufacture, the material would be too brittle for oil-field usage.

Asbestos-Cement Pipe With Metal Couplings

Asbestos-cement pipe is practical for oil-field surface lines to conduct salt water, and when cemented in it is competent as casing for salt-water-disposal wells of moderate depth. Greater depths may be cased if the casing is floated into a hole full of fluid. The strength of threaded metal couplings on threaded asbestos-cement pipe has been demonstrated in the test of the 5-in. asbestos-cement pipe coupled with a 6-in. steel coupling. Stainless steel combined with asbestos-cement pipe provides a corrosion-proof casing and pipe line.

Plastic Couplings

Fig. 8 shows a 2-in. plastic coupling set up for a test to destruction by tension and the coupling after destruction. This was pulled apart in the Talbot laboratory at 2,890 lb. The area of plastic is 3.4 in., so that the strength is 825 psi. A plastic coupling to connect two joints of ¾-in. by 6-in. asbestos cement pipe would have to be 1.1 in. thick to make the plastic coupling and asbestos-cement pipe of equal strength. Since this is rather thick, its cross-section may be reduced by reinforcement. Reinforcing plastics with glass fiber is very successful, and metal reinforcement has given promising results (see Fig. 12). By either reinforcing means, the cross-section of the plastic coupling may be greatly reduced at no expense of strength. The use of plastics instead of cement for protection behind metal or for strength behind nonmetallic casing for wells presents interesting possibilities.

Conclusions

Perfecting of corrosion-proof pipe lines and cemented-in casing has a postwar as well as a wartime use. The investigations outlined in this article are a start in this direction. They demonstrate that asbestos-

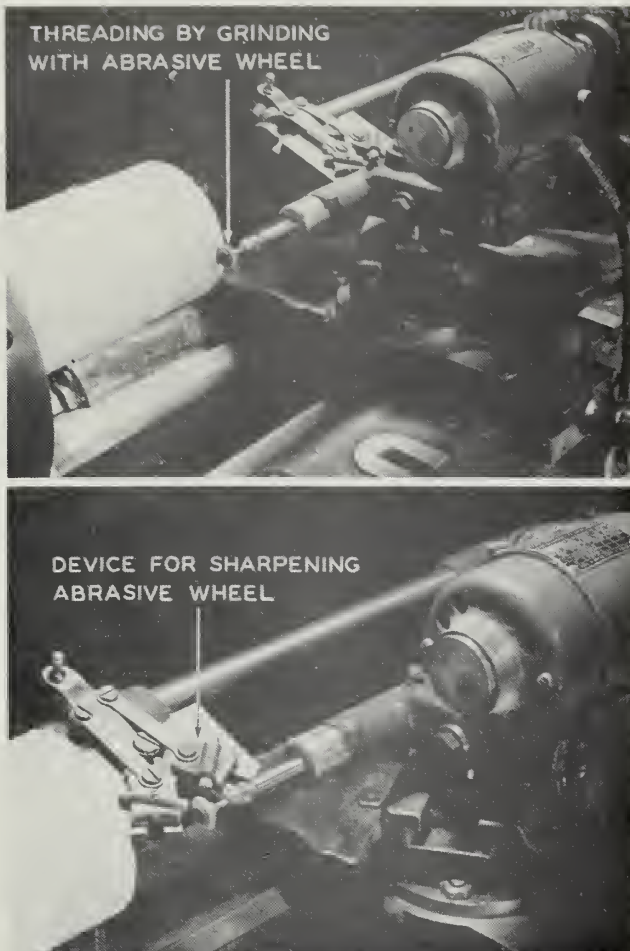


Fig. 11—(Right) Upper figure: High-speed grinding equipment mounted on ordinary lathe, used for grinding exterior and interior threads on asbestos cement or plastic pipe and couplings. Lower figure: Device for sharpening abrasive wheel

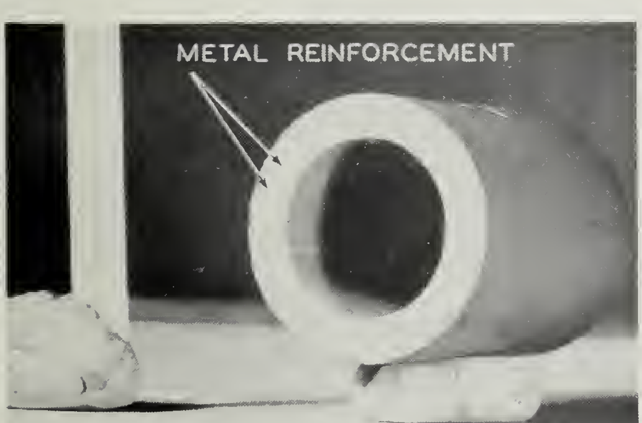


Fig. 12—(Left) Short section of plastic pipe, reinforced with parallel metal rods contacting spiral reinforcement. The pipe has been ground down to expose reinforcement which normally would be entirely covered by plastic

cement pipe may be successfully threaded by grinding and joined by stainless steel or plastic threaded couplings to form a line sufficiently strong to provide practical pressure surface lead lines and may be cemented in as casing in wells of considerable depth for oil-field salt-water disposal. Strings of corrosion-proof pipe to take smaller loads for the same purposes may be made of threaded fiber pipe united with plastic couplings, and reinforced cement-lined fiber pipe may be used for intermediate pressures and depths. Plastic couplings may be reinforced with glass fiber or metal and used to join either asbestos-cement or fiber pipe.

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